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FINAL REPORT
FOR
JANTX 2N2432A

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Prepared
For

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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics And Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.



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1.0 INTRODUCTION

DCA Reliability Laboratory, under contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the transistor JANTX2N2432A manufactured by Crystalonics and Texas Instruments.

A total of 48 samples from each manufacturer were submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 High-Speed Computer-Controlled Tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The current was set by I_E and the voltage was varied in order to comply with the specified power rating for this device. At least one of the devices was subjected to maximum rated power (MRP). All remaining devices were subjected to no less than 90% of MRP. See Figure 1 for load resistance values and voltages.



2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent MRP for a total of 2500 hours or until 50% or more of the devices in the sample lot failed*. Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1.

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I process. Group II was subjected to 1600 hours of stress at MRP in increments of 160 hours. The temperature was increased in steps of +25°C, commencing at +75°C and terminating at +300°C or until 50% or more of the devices failed*. Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II process. Group III was subjected to 112 hours of stress at MRP in increments of 16 hours. The temperature was increased in steps of +25°C, commencing at +150°C and terminating at +300°C or until 50% or more of the devices in a sample lot failed*. Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

*Conditions for failure:

- A) Open or short
- B) Leakage exceeds the MIL limits by 100 times
- C) Other parameters exceed MIL limits by 50% or more



3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Texas Instruments. The Texas Instruments sample lot completed the entire 2500-hour Group I testing with six catastrophic failures. The first failure occurred 150 hours into the 175% MRP step. Serial number 8712 failed the maximum I_{CBO} limit. The last five failures occurred 250 hours into the 175% MRP step. Serial numbers 8708 and 8710 failed the maximum I_{CBO} and h_{FE} limits. Serial numbers 8713, 8716 and 8717 failed the maximum $V_{CE(SAT)}$ limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 26.6pA from an initial mean of 135.6pA to a final mean of 109.0pA.
- 2) The mean value for $V_{CE(SAT)}$ changed .83mV from an initial mean of 77.63mV to a final mean of 76.8mV.
- 3) The mean value for h_{FE} changed 3.3 from an initial mean of 112.8 to a final mean of 109.5.

The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.2 Crystallonics. The Crystallonics sample lot completed the entire 2500-hour Group I testing with no catastrophic failures. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 112.5pA from an initial mean of 290.6pA to a final mean of 178.1pA.
- 2) The mean value for $V_{CE(SAT)}$ changed .94mV from an initial mean of 68.63mV to a final mean of 67.69mV.
- 3) The mean value for h_{FE} changed .70 from an initial mean of 49.22 to a final mean of 48.52.



The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.3 Statistical Summary - Group I

Table 4 outlines the results of Group I - Power Stress process for each of the electrical parameters and all measurement points for both Texas Instruments and Crystalonics.

3.2 Group II - Temperature Stress I

3.2.1 Texas Instruments. The Texas Instruments sample lot completed a total of 1120 hours before the lot was stopped because 50% of the devices failed. The first failure occurred 160 hours into the +175°C-temperature step. Serial number 8731 failed the minimum h_{FE} limit. The next failure occurred 160 hours into the +200°C-temperature step. Serial number 8736 failed the maximum I_{CBO} limit. The last six failures occurred 160 hours into the +225°C-temperature step. Serial numbers 8728 and 8733 failed the maximum I_{CBO} limit. Serial numbers 8721, 8724, 8727 and 8734 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 544.8nA from an initial mean of <0.00pA to a final mean of 544.8nA.
- 2) The mean value for $V_{CE(SAT)}$ changed 6.83mV from an initial mean of 76.81mV to a final mean of 83.64mV.
- 3) The mean value for h_{FE} changed 154.7 from an initial mean of 115.2 to a final mean of 269.9.

The control units for this sample lot remained constant throughout the entire Group II testing.



3.2.2 Crystalonics. The Crystalonics sample lot completed the entire 1600-hour Group II testing with 10 catastrophic failures. The first failure occurred 160 hours into the +200°C-temperature step. Serial number 8788 failed the minimum h_{FE} limits. The next three failures occurred 160 hours into the +250°C-temperature step. Serial number 8776 failed the maximum I_{CBO} limit. Serial number 8781 failed the minimum h_{FE} limit. Serial number 8787 failed the maximum $V_{CE(SAT)}$ limit. Serial number 8785 was also removed from the testing at this point as a MIL-8-19500 limit failure. The next two failures occurred 160 hours into the +275°C-temperature step. Serial number 8778 failed the maximum I_{CBO} and the minimum h_{FE} limits. Serial number 8782 failed the minimum h_{FE} limit. The last four failures occurred 160 hours into the +300°C-temperature step. Serial numbers 8775, 8784 and 8789 failed the minimum h_{FE} limit. Serial number 8779 failed the maximum I_{CBO} and minimum h_{FE} limits. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 9.602uA from an initial mean of 3.75pA to a final mean of 9.602uA.
- 2) The mean value for $V_{CE(SAT)}$ changed 44.71mV from an initial mean of 66.69mV to a final mean of 111.4mV.
- 3) The mean value for h_{FE} changed 40.27 from an initial mean of 66.64 to a final mean of 26.37.

The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.3 Statistical Summary - Group II

Table 5 outlines the results of Group II - Temperature Stress I testing for each of the electrical parameters and all of the measurement points pertaining to both Texas Instruments and Crystalonics.



3.3 Group III - Temperature Stress II

3.3.1 Texas Instruments. The Texas Instruments sample lot completed the total 112-hour Group III testing with 10 catastrophic failures. The first failure occurred 16 hours into the +225°C-temperature step. Serial number 8740 failed the minimum h_{FE} limit. The next six failures occurred 16 hours into the +275°C-temperature step. Serial numbers 8740, 8743, 8747, 8748, 8751 and 8752 failed the minimum h_{FE} limit. The last three failures occurred 16 hours into the +300°C-temperature step. Serial numbers 8744, 8749, and 8750 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 160.51nA from an initial mean of 190.6pA to a final mean of 160.70nA.
- 2) The mean value for $V_{CE(SAT)}$ changed 4.49mV from an initial mean of 78.81mV to a final mean of 83.3mV.
- 3) The mean value for h_{FE} changed 40.60 from an initial mean of 104.4 to a final mean of 63.80.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.2 Crystalonics. The Crystalonics sample lot completed the entire 112-hour Group III testing with a total of eight catastrophic failures. The first two failures occurred 16 hours into the +275°C-temperature step. Serial numbers 8794 and 8796 failed the minimum h_{FE} limit. The last six failures occurred 16 hours into the +300°C-temperature step. Serial numbers 8791, 8795, 8800, 8801 and 8804 failed the minimum h_{FE} limits. Serial number 8803 failed the



maximum $V_{CE(SAT)}$ limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 93.95nA from an initial mean of 289.4pA to a final mean of 94.24nA.
- 2) The mean value for $V_{CE(SAT)}$ changed 718.2mV from an initial mean of 64.5mV to a final mean of 782.7mV.
- 3) The mean value for h_{FE} changed 25.49 from an initial mean of 69.20 to a final mean of 43.71.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.3 Statistical Summary - Group III

Table 6 outlines the results of Group III - Temperature Stress II testing for each of the electrical parameters and all of the measurement points pertaining to both Texas Instruments and Crystalonics.

4.0 FINAL DATA SUMMARY

Table 7 summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 through 5 plot the cumulative percent failures versus time at temperature stress levels for Group II - Temperature Stress I, and Group III - Temperature Stress II. Tables 8 and 9 summarize the failures encountered for all three stress groups. The test devices are separated into two groups: catastrophic failures shown in Table 8 and parametric failures shown in Table 9. The data from Table 8 was used as a source for the graphs in Figures 2 through 5.



5.0

CONCLUSIONS

The Crystalonics sample lot showed no catastrophic failures in the Group I testing, but the Texas Instruments sample lot experienced six catastrophic failures towards the end of the testing. The durability of the Crystalonics lot becomes more apparent in the Group II - Temperature Stress I testing. Although the Crystalonics lot experienced a greater total number of catastrophic failures, it was able to complete the entire Group II testing. The Texas Instruments lot had to be stopped at the +225°C temperature step with a total of eight catastrophic failures. Note that the majority of the failures at this point are h_{FE} failures. This can indicate a change in emitter injection efficiency due to a diffusion of gold into the base under heat and bias over many hours. Once again in the Group III - Temperature Stress II testing, the Crystalonics lot proved to be more hardy than Texas Instruments with eight failures compared to ten. Failure analysis shows that many of the failures developed weak emitter-base junctions. The high temperatures of the stress tests liberated sufficient contaminant within the devices so that both sample lots exhibited base inversions. The formation of gold-silicon intermetallics probably expedited the migration of contaminants by chemical attack on the oxide near the junctions.

A graph showing cumulative failure distribution for Groups II and III was drawn for the Texas Instruments and Crystalonics sample lot (Figures 2 and 3; 4 and 5, respectively).

Figures 2 and 3 display the data for the Texas Instruments lot used to calculate an activation energy of 1.70eV.

Figures 4 and 5 display the data for the Crystalonics lot used to calculate an activation energy of 1.29eV.



A broken circle around a marked point on the graph indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated main failure point. The regression line was calculated using the least squares method.

Because of visual defects caused by the extreme heat of the stress tests, serial numbers 8796 and 8803 were not calculated as part of the regression line.

Because of changes in the failure mechanisms, the Group II failure points at 375°C & 400°C in Figure 2 and the Groups II and III failure points at 475°C in Figure 3 were not calculated into the respective regression lines.

The activation energy was calculated from the formula:

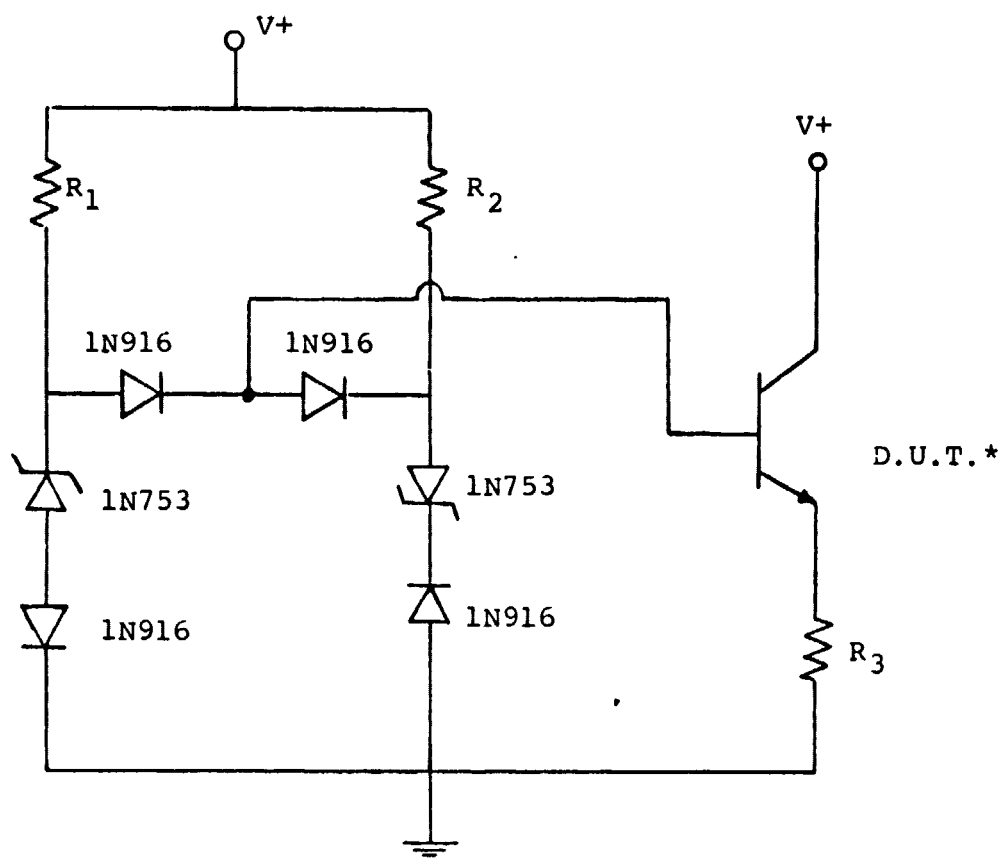
$$E = \left[\ln \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^\circ\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{ eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^\circ\text{C}$ of 16% failure for Group II.

T_2 = temperature in $^\circ\text{C}$ of 16% failure for Group III.



$$R_1 = R_2 = 800\Omega \pm 5\%, 2W$$

For V+ see Table 3

$$R_3 = 150\Omega \pm 1\%, 1/2 W$$

* D.U.T. = Device Under Test

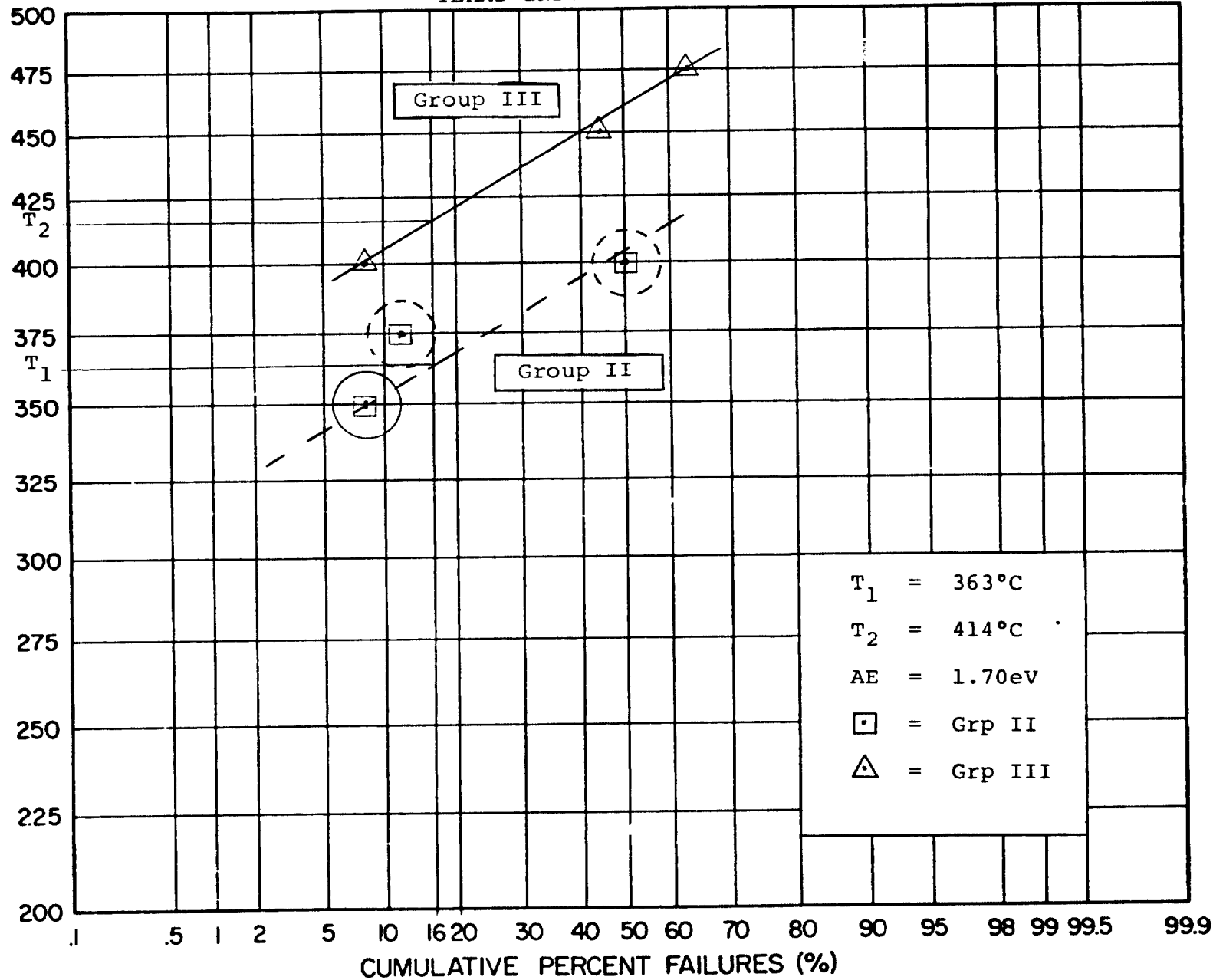
FIGURE 1
Power and Temperature Stress Circuit for JANTX2N2432A



TEXAS INSTRUMENTS

JANTX2N2432A

* JUNCTION TEMPERATURE (°C)



JANTX2N2432A

*NOTE

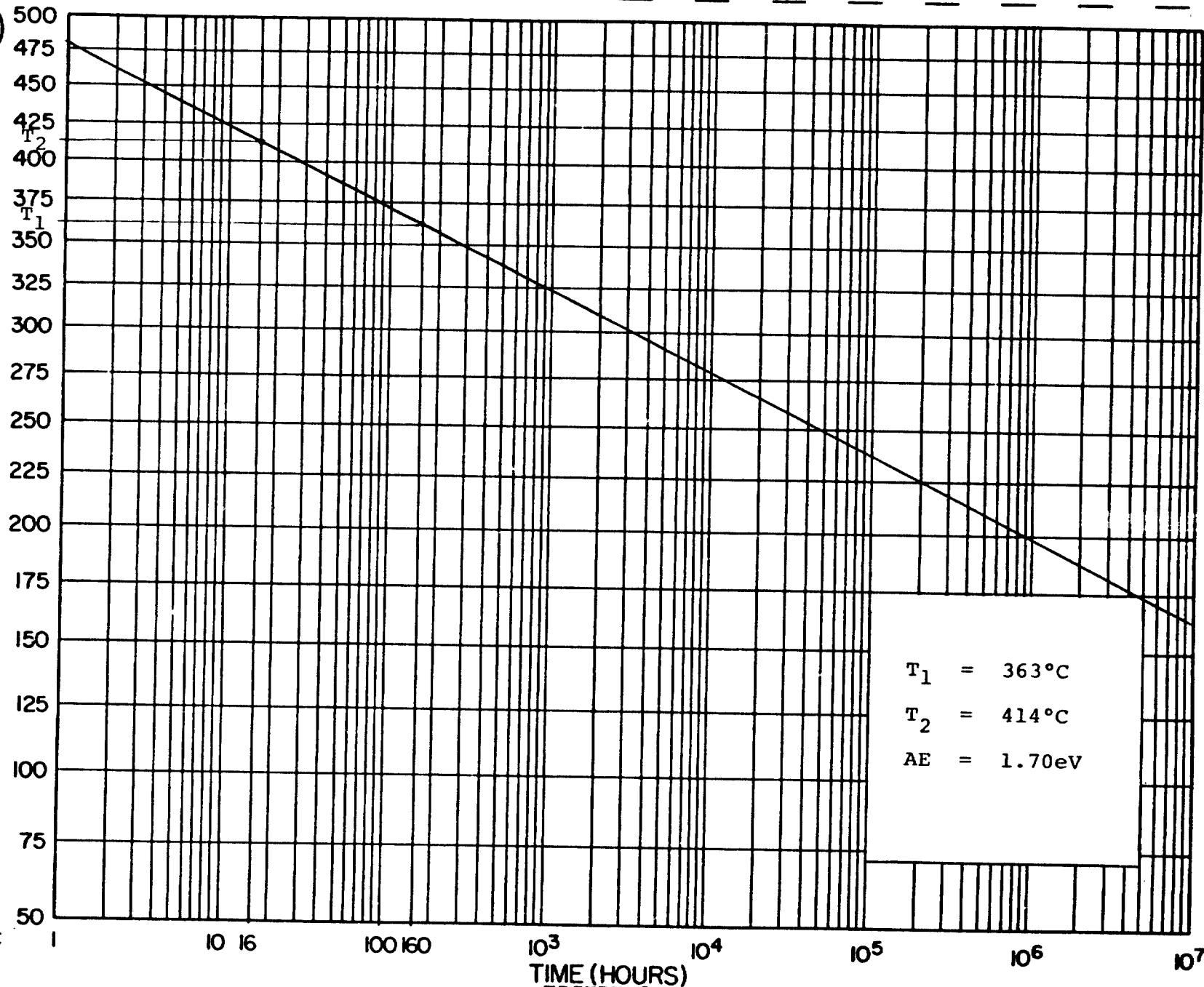
$$T_J \approx T_A + 175^\circ\text{C}$$

FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, Texas Instruments



* JUNCTION TEMPERATURE (°C)



JANTX2N2432A

*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$

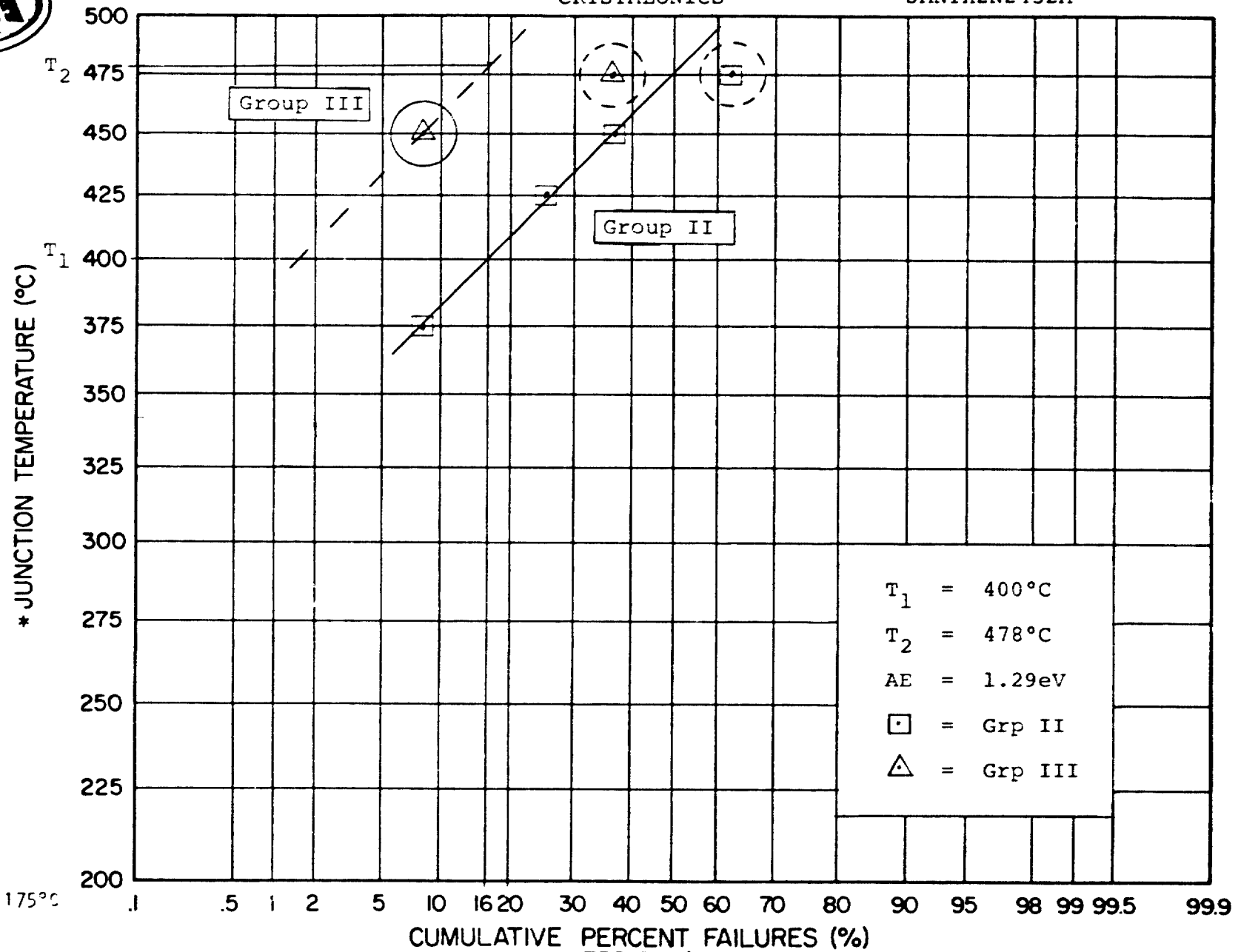
TIME (HOURS)
FIGURE 3

Time Steps Versus Junction Temperature, Texas Instruments



CRYSTALONICS

JANTX2N2432A

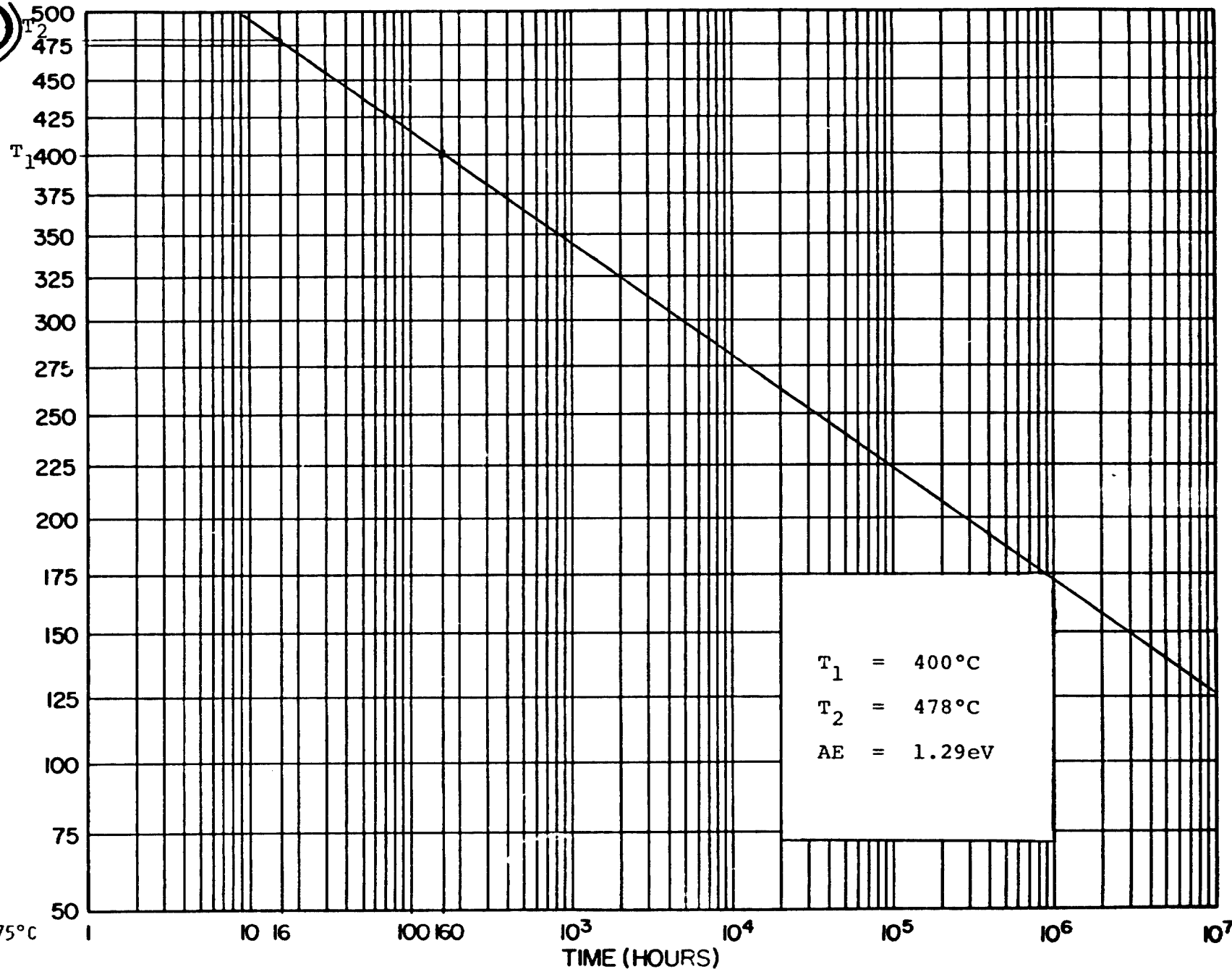


JANTX2N2432A

FIGURE 4
Cumulative Percent Failures Versus Junction Temperature, Crystalonics



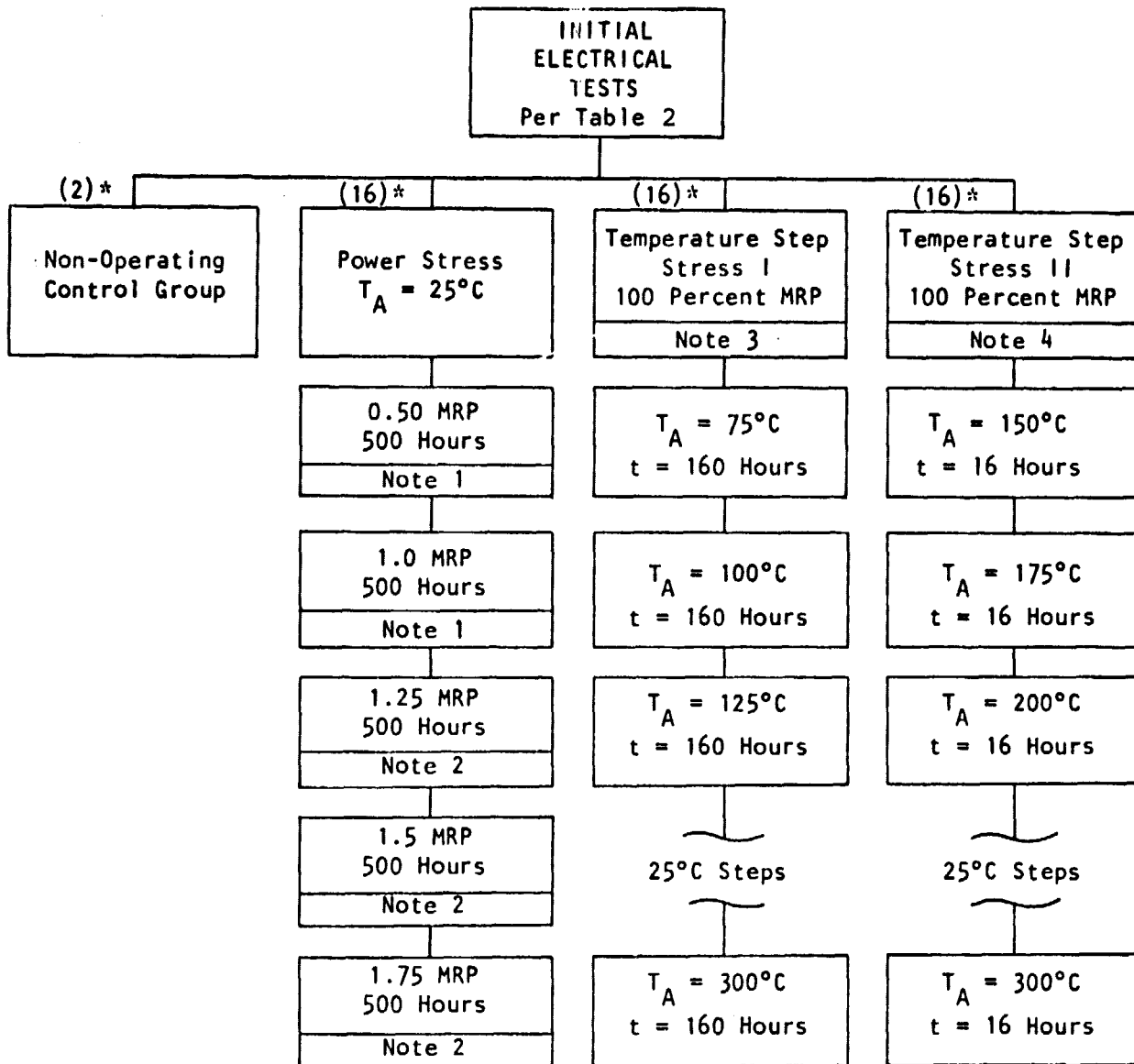
* JUNCTION TEMPERATURE (°C)



12A

JANTX2N2432A

FIGURE 5
Time Steps Versus Junction Temperature, Crystalonics

TABLE 1
TEST FLOW DIAGRAM

*Quantity per manufacturer (Crystalonics & Texas Instruments)

NOTES:

- 1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
- 2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
- 3) Electrical measurements per Table 2 were made at the end of each 160 hours.
- 4) Electrical measurements per Table 2 were made at the end of each 16 hours.



JANTX2N2432A

TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	@ $V_{CB} = 40V$		10		1000	nA
$V_{CE(SAT)}$	@ $I_C = 10.0mA$ & $I_B = 0.5mA$		.15		.225	V
h_{FE}	@ $V_{CE} = 5.0V$ & $I_C = 10.0\mu A$	30	900	15	1350	

NOTES:

TABLE 3
POWER STRESS BURN-IN CONDITIONS

$I_E = 20.0mA$	
V_{CE}	Percent P_D
7.5V	50
15.0V	100
18.75V	125
22.5V	150
26.25V	175



NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of $\pm 1\%$ of the reading and $\pm$ one digit except for readings greater than 9.99mA which have an absolute accuracy of $\pm 2\%$ of the reading and $\pm$ one digit. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.



TABLE 4
GROUP I - POWER STRESS DATA SUMMARY

Page 1 of 2

PARAMETER	$I_{CBO} = 10\text{nA (Max)}$		$h_{FE} = 30 \text{ (Min) } 900 \text{ (Max)}$		$V_{CE(SAT)} = .15\text{V (Max)}$			
CONDITIONS AND LIMIT	$V_{CB} = 40\text{V}$		$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$		$I_C = 10\mu\text{A}, I_B = 500\mu\text{A}$			
IDENTIFICATION	TI	CRY	TI	CRY	TI	CRY		
INITIAL DATA								
MIN VALUE	90.0pA	90.0pA	85.1	33.9	67.0mV	49.0mV		
MAX VALUE	220.0pA	1.80nA	181.0	93.3	85.0mV	93.0mV		
MEAN	135.6pA	290.6pA	112.8	49.2	77.63mV	68.63mV		
STD DEV	39.37pA	472.4pA	25.23	19.95	4.910mV	13.03mV		
INTERIM DATA								
POWER 50 TO 125%								
Δ MEAN VALUE								
50% POWER								
50 Hours	-18.7pA	-12.5pA	-.6	-.26	-0.00mV	-.32mV		
150 Hours	14.4pA	138.1pA	-2.0	2.19	-.82mV	-.32mV		
250 Hours	-23.7pA	-49.4pA	-1.2	1.15	-1.25mV	-1.07mV		
500 Hours	-31.90pA	-103.7pA	-3.2	-.63	-1.38mV	-1.25mV		
100% POWER								
550 Hours	-37.5pA	-60.6pA	3.8	4.74	-.88mV	-.88mV		
650 Hours	-31.2pA	-83.7pA	2.9	4.33	1.07mV	-1.19mV		
750 Hours	-23.7pA	-91.2pA	.1	4.10	-.94mV	-1.07mV		
1000 Hours	-30.0pA	-90.6pA	.8	3.53	1.06mV	.75mV		
125% POWER								
1010 Hours	-39.4pA	-126.9pA	-1.5	-0.00	.93mV	.56mV		
1025 Hours	2.5pA	-46.2pA	-1.4	3.10	1.87mV	2.12mV		
1050 Hours	-10.0pA	-49.4pA	-.7	5.55	1.68mV	2.43mV		
1150 Hours	-6.9pA	-92.5pA	-2.1	1.17	3.12mV	2.43mV		
1250 Hours	-10.6pA	-75.6pA	.7	3.74	1.62mV	.50mV		
1500 Hours	-9.4pA	-68.1pA	-.1	2.39	2.06mV	1.37mV		

(continued on second sheet)



TABLE 4 (Cont'd)

(continued from first sheet)

GROUP I - POWER STRESS DATA SUMMARY

Page 2 of 2

PARAMETER	$I_{CBO} = 10\text{nA (Max)}$		$h_{FE} = 30 \text{ (Min) } 900 \text{ (Max)}$		$V_{CE(SAT)} = .15\text{V (Max)}$			
CONDITIONS AND LIMITS	$V_{CB} = 40\text{V}$		$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$		$I_C = 10\mu\text{A}, I_B = 500\mu\text{A}$			
IDENTIFICATION	TI	CRY	TI	CRY	TI	CRY		
INITIAL DATA								
MIN VALUE	90.0pA	90.0pA	85.1	33.9	67.0mV	49.0mV		
MAX VALUE	220.0pA	1.80nA	181.0	93.3	85.0mV	93.0mV		
MEAN	135.6pA	290.6pA	112.8	49.22	77.63mV	68.63mV		
STD DEV	39.37pA	472.4pA	25.23	19.95	4.910mV	13.03mV		
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 Hours	-25.0pA	-33.7pA	-2.4	3.37	1.12mV	-.38mV		
1525 Hours	-16.9pA	-97.5pA	-1.9	2.59	2.12mV	1.56mV		
1550 Hours	-21.9pA	-86.9pA	-3.8	1.07	2.50mV	1.81mV		
1650 Hours	-11.2pA	-111.2pA	-2.5	1.63	.93mV	.81mV		
1750 Hours	-16.2pA	-93.1pA	-5.5	1.49	1.37mV	.68mV		
2000 Hours	-11.2pA	-76.9pA	-8.1	1.10	2.12mV	.62mV		
175% POWER								
2010 Hours	-22.5pA	-103.7pA	-8.7	1.66	1.68mV	.62mV		
2025 Hours	7.825nA	-133.7pA	-9.1	-1.25	1.87mV	-0.00mV		
2050 Hours	36.664nA	-113.1pA	-8.2	.10	2.18mV	.81mV		
2150 Hours	*624.364nA	-130.0pA	-10.2	-3.44	.87mV	-.82mV		
2250 Hours	*374.686nA	-110.0pA	*273.2	1.92	*106.77mV	-.75mV		
2500 Hours	-26.6pA	-112.5pA	-3.3	-.70	-.83mV	-.94mV		
FINAL DATA								
MIN VALUE	40.0pA	80.0pA	81.8	26.10	69.0mV	51.0mV		
MAX VALUE	180.0pA	1.08nA	170.0	85.40	82.0mV	95.0mV		
MEAN	109.0pA	178.1pA	109.5	48.52	76.8mV	67.69mV		
STD DEV	44.15pA	238.9pA	24.38	17.53	3.97mV	13.63mV		

*NOTE: Catastrophic Rejects removed from data.



TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY (160 Hour)

PARAMETERS	$I_{CBO} = 10\text{nA (Max)}$		$h_{FE} = 30 \text{ (Min) } 900 \text{ (Max)}$		$V_{CE(SAT)} = .15\text{V (Max)}$			
CONDITIONS AND LIMITS	$V_{CB} = 40\text{V}$		$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$		$I_C = 10\text{mA}, I_B = 500\mu\text{A}$			
IDENTIFICATION	TI	CRY	TI	CRY	TI	CRY		
INITIAL DATA								
MIN VALUE	0.00pA	0.00pA	91.7	34.5	70.0mV	59.0mV		
MAX VALUE	0.00pA	60.0pA	163.0	132.0	84.0mV	91.0mV		
MEAN	0.00pA	3.75pA	115.2	66.64	76.81mV	66.69mV		
STD DEV	0.00pA	14.52pA	16.93	22.62	3.206mV	10.25mV		
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE (T_A)								
<u>Total Hrs</u> <u>Temp</u>								
160 Hours +75°C	+1.25pA	108.75pA	.5	.25	.38mV	.06mV		
320 Hours +100°C	+ .50pA	104.35pA	.9	.85	.94mV	.75mV		
480 Hours +125°C	+0.00pA	152.45pA	-9.2	-4.05	-.56mV	-1.06mV		
640 Hours +150°C	+104.4pA	71.25pA	-9.5	-3.62	-1.62mV	-1.81mV		
800 Hours +175°C	*+40.06nA	378.15pA	46.2	9.08	4.38mV	-1.00mV		
960 Hours +200°C	+4.344nA	2.253nA	8.4	23.70	5.76mV	-1.00mV		
1120 Hours +225°C	*+544.8nA	2.488uA	*154.7	*108.16	6.83mV	11.38mV		
1280 Hours +250°C	Job	*832.9uA	Job	*96.26	Job	*712.91mV		
1440 Hours +275°C	Stopped	*1.360uA	Stopped	* 6.89	Stopped	* 22.11mV		
1600 Hours +300°C		*9.602uA		*-40.27		* 44.71mV		
FINAL DATA								
FINAL TEMP (T_A)	+225°C	+300°C	+225°C	+300°C	+225°C	+300°C		
MIN VALUE	0.00 pA	0.00 pA	1.6	1.6	9.0mV	63.0mV		
MAX VALUE	5.35uA	86.0uA	999.0	80.0	140.0mV	199.0mV		
MEAN	544.8nA	9.602uA	269.9	26.37	83.64mV	111.4mV		
STD DEV	1.391uA	27.01uA	382.8	29.49	25.76mV	44.35mV		

-NOIE: CATASTROPHIC REJECTS REMOVED FROM DATA



TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY (16 HOUR)

PARAMETERS	$I_{CBO} = 10\text{nA (Max)}$		$h_{FE} = 30 \text{ (Min) } 900 \text{ (Max)}$		$V_{CE(SAT)} = .15\text{V (Max)}$			
CONDITIONS AND LIMITS	$V_{CB} = 40\text{V}$		$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$		$I_C = 10\text{mA}, I_B = 500\mu\text{A}$			
IDENTIFICATION	TI	CRY	TI	CRY	TI	CRY		
INITIAL DATA								
MIN VALUE	80.0pA	40.0pA	77.3	32.2	71.0mV	43.0mV		
MAX VALUE	1.17nA	3.15nA	131.0	121.0	131.0mV	88.0mV		
MEAN	190.6pA	289.4pA	104.4	69.2	78.81mV	64.5mV		
STD DEV	255.2pA	738.8pA	14.44	23.05	3.225mV	10.85mV		
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE (T_A)								
TOTAL HRS	TEMP							
16	+150°C	261.3pA	162.5pA	-34.59	.61	-14.37mV	-.06mV	
32	+175°C	-14.4pA	53.1pA	5.20	2.11	-1.62mV	-.56mV	
48	+200°C	-2.5pA	235.6pA	7.60	4.49	-1.06mV	-.25mV	
64	+225°C	46.51nA	980.6pA	-8.03	21.11	.32mV	.19mV	
80	+250°C	52.7pA	1.41nA	2.60	*25.30	-.48mV	.38mV	
96	+275°C	82.88nA	3.24nA	*-40.47	-.64	2.66mV	.44mV	
112	+300°C	160.51nA	93.95nA	*-40.60	*-25.49	4.49mV	*718.2mV	
FINAL DATA								
FINAL TEMP (T_A)	+300°C	+300°C	+300°C	+300°C	+300°C	+300°C		
MIN VALUE	100.0pA	50.0pA	0.00	0.00	79.0mV	59.0mV		
MAX VALUE	999.0nA	999.0nA	124.0	126.0	88.0mV	9.99V		
MEAN	160.7nA	94.24nA	63.80	43.71	83.3mV	782.7mV		
STD DEV	311.6nA	253.8nA	47.56	42.71	2.795mV	2.554V		

*NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		U N I T S	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
	MIN	MAX			POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
					TI	CRY	TI	CRY	TI	CRY
I _{CBO}		10	NA		+40.120 *	-.07748	-84.187 *	+84635. *	+41.457	+14.290
h _{FE}	30	900	--		+7.8846 *	+1.7169	+27.429 *	+19.725 *	-15.470 *	+3.9271 *
V _{CE(SAT)}		.15	V		+.00495	+.00031	+.00230	+.07869 *	-.00144	+.10262 *

*NOTE: Catastrophic reject(s) removed from data.



TABLE 8 STEP STRESS Catastrophic FAILURE SUMMARY

JAN TX2N2432A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	1	A	0	-
100 hr.	2	3 C D	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP TA	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	-	0	-
100° C	0	-	0	-
125° C	0	-	0	-
150° C	0	-	0	-
175° C	1	E	0	-
200° C	1	A	1	E
225° C	4	2 E A	0	-
250° C	Job Stopped		1	1 A D E
275° C			1	F E
300° C			3	1 E F

GROUP III 16 HR. TEMP. STEPS

TEST STEP TA	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150° C	0	-	0	-
175° C	0	-	0	-
200° C	0	-	0	-
225° C	1	E	0	-
250° C	0	-	0	-
275° C	6	E	2	E
300° C	3	E	5	1 E D

NOTES:

- A) $I_{CBO} > 1.0 \mu A$
- B) $h_{FE} > 1350$
- C) Notes A&B
- D) $V_{CE(SAT)} > .225V$
- E) $h_{FE} < 15$
- F) Notes A&E

MFG "E" = Texas Instruments
MFG "E" = Crystalonics



TABLE 9 STEP STRESS Parametric FAILURE SUMMARY

JAN TX2N2432A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	1	B
25 hr.	1	A	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	0	-	0	-
100°C	0	-	0	-
125°C	0	-	0	-
150°C	0	-	0	-
175°C	1	A	0	-
200°C	1	A	1	A
225°C	1	C	1	A D
250°C	Job Stopped		0	-
275°C			0	-
300°C			1	B

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	0	-	1	A
250°C	0	-	1	A
275°C	0	-	1	B
300°C	1	A	0	-

MFG "A" = Texas Instruments
MFG "B" = Crystalonics

NOTES:

- A) I_{CBO} Maximum Limit Failure
- B) h_{FE} Minimum Limit Failure
- C) S/N 8785 Removed From Testing As A MIL-S-19500 Limit Failure
- D) $V_{CE(SAT)}$ Maximum Limit Failure



JANTX2N2432A

APPENDIX

FAILURE ANALYSIS



FAILURE ANALYSIS

JANTX2N2432A

Date April 4, 1978

J/N 2CN242-09C P/N 2N2432A(NPN) MFR Texas Instruments

FAILURE VERIFICATION:

S/N	BV_{CEO} Volts	BV_{CBO} Volts	I_{CBO} uA @ $V_{CB}=40V$	BV_{EBO} Volts	h_{FE} @ $I_C=10uA$ $V_{CE}=5V$	V_{BEO} Volts @ $I_{BEO}=10mA$	Initial Rej. @ Test Seq. No.:	Initial Rej. for
8739	105	240	<0.2	21	1.54	0.79	15	h_{FE}
8740	0.51	215 INV	0.5	21	.50*	0.88	09	CAT
* h_{FE} @ 10uA.	read @ 80uA. Because of collector leakage sample could not be measured							
8741	84 INV	220	0.2	21	.62	0.78	15	I_{CBO}

INTERNAL VISUAL INSPECTION:

All samples exhibit gold-aluminum intermetallics. (See Figure A-1.)

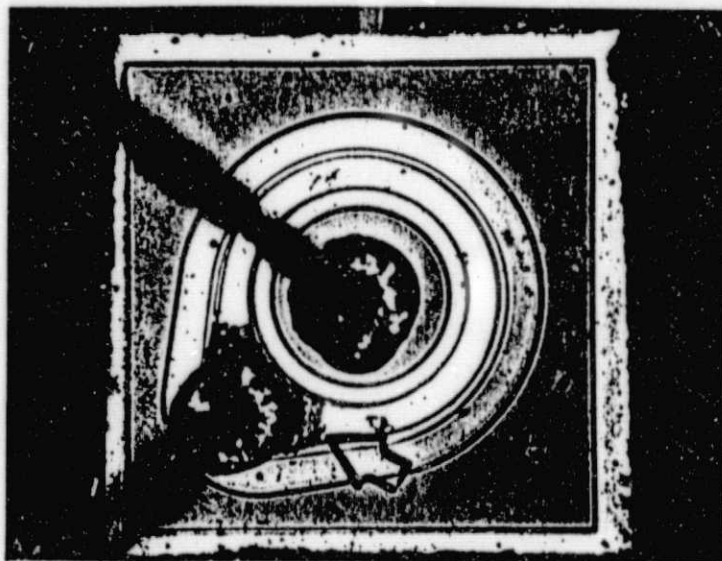
S/N 8740 also has a cracked and floating die. (See Figure A-2.)

* h_{FE} trace present. Cannot meet stated test conditions. (Leaky)** h_{FE} trace very leaky.

D = drift H = hysteresis Inv = inversion R = resistive S = soft Uns = unstable



JANTX2N2432A



ORIGINAL IMAGE IS
OF POOR QUALITY

FIGURE A-1
S/N 8739. Texas Instruments Device, 152X
Typical die geometry. Arrow indicates
"purple plague".



FIGURE A-2
S/N 8740. Texas Instruments Device, 100X
Cracked and floating die. (Still makes
electrical contact and functions.)



FAILURE ANALYSIS

JANTX2N2432A

Date April 4, 1978

J/N 2CN242-09C P/N 2N2432A(NPN) MFR Crystalonics

FAILURE VERIFICATION:

S/N	BV_{CEO} Volts	BV_{CBO} Volts	I_{CBO} uA @ $V_{CB}=40V$	BV_{EBO} Volts	h_{FE} @ $I_C=10uA$ $V_{CE}=5V$	V_{BEO} Volts $I_{BEO}=10mA$	Initial Rej. @ Test Seq. No.:	Initial Rej. for
8793	70 INV ⁺	195 INV ⁺	<0.2	82	40	0.9	11	I_{CBO}
8796	70	230	<0.2	81	8	0.88	11	CAT
8803	164 OSC	165 OSC	<0.2	0.1R	1.25	0.88	13	h_{FE}

INTERNAL VISUAL INSPECTION:

All samples contain gold-aluminum intermetallics on the base and emitter gold ball bonds. (See Figures A-3 and A-4.)

S/N 8803 has gold-aluminum intermetallics on the emitter-base junction. (See Figure A-4.)

+Inversions disappeared after opening case.

* h_{FE} trace present. Cannot meet stated test conditions. (Leaky)

** h_{FE} trace very leaky.

D = drift H = hysteresis Inv = inversion R = resistive S = soft Uns = unstable



JANTX2N2432A

ORIGINAL PAGE IS
OF POOR QUALITY

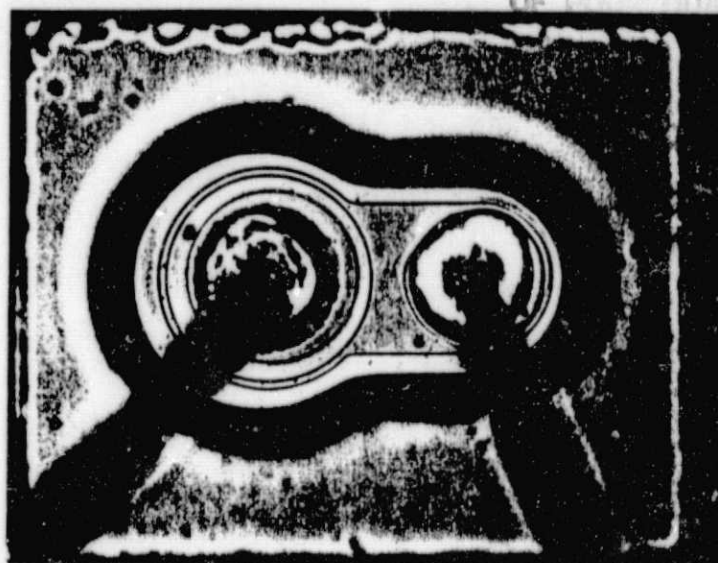


FIGURE A-3
S/N 8793, Crystalonics Device, 184X
Typical die geometry.

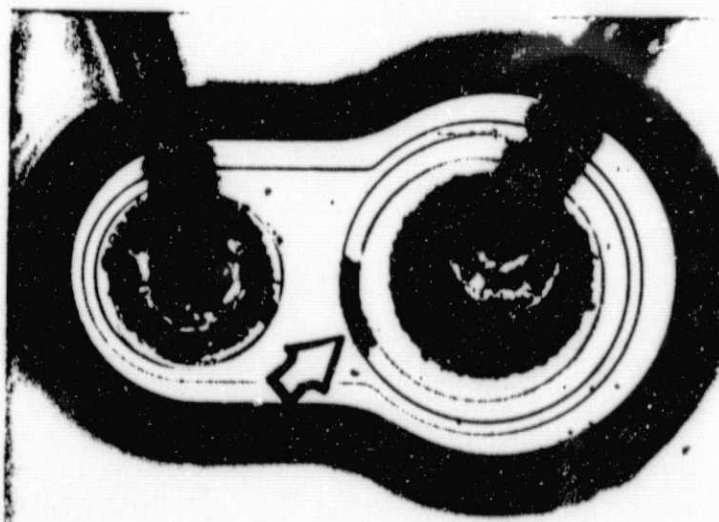


FIGURE A-4
S/N 8893, Crystalonics Device, 272X
Arrow indicates misplaced gold-aluminum
intermetallics on emitter-base junction.
Note some material at base and emitter
gold wire bonds.



CONCLUSIONS:

Both Crystallonics and T.I. are using approximately 4 ohm-cm silicon. At this resistivity surface problems can appear. The unusually high ambient temperatures of the stress tests liberated sufficient contaminants within the devices so that both companies' products exhibited base inversions. The formation of gold-silicon intermetallics probably expedited the migration of contaminants by chemical attack on the oxide near the junctions. Specific failure modes are as follows:

CRYSTALLONICS:

S/N 8793 - Inversion on the collector and base has caused I_{CBO} to go out of test limits. The device has recovered sufficiently in storage so that it was acceptable at the time of this failure analysis.

S/N 8796 - All measured parameters are acceptable and yet the device has developed a very low h_{FE} . This indicates a change in emitter injection efficiency due to the diffusion of gold into the base under heat and bias over many hours.

S/N 8803 - This device has a shorted emitter-base junction due either to chemical attack on the oxide by the misplaced metallization or to electrical overstress caused by oscillation. (See electrical data and Figure 4.)

TEXAS INSTRUMENTS:

S/N 8739 - All measured parameters are acceptable and yet the device has developed a very low h_{FE} . This indicates a change in emitter injection efficiency due to the diffusion of gold into the base under heat and bias over many hours.

S/N 8740 - Cracked and floating die, although still connected electrically.

S/N 8741 - Same as S/N 8739 but with a greater amount of inversion.